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# RESEARCH

## Intervention strategies to reduce the burden of non-communicable diseases in Mexico: cost effectiveness analysis



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Joshua A Salomon *associate professor of international health*<sup>1</sup>, Natalie Carvalho *doctoral student*<sup>2</sup>, Cristina Gutiérrez-Delgado *deputy director general of economics and health*<sup>3</sup>, Ricardo Orozco *analyst*<sup>4</sup>, Anna Mancuso *clinical social worker*<sup>5</sup>, Daniel R Hogan *postdoctoral fellow*<sup>6</sup>, Diana Lee *doctoral student*<sup>7</sup>, Yuki Murakami *health economist/policy analyst*<sup>8</sup>, Lakshmi Sridharan *resident in internal medicine*<sup>9</sup>, María Elena Medina-Mora *director general*<sup>4</sup>, Eduardo González-Pier *director of finance*<sup>10</sup>

<sup>1</sup>Department of Global Health and Population, Harvard School of Public Health, 665 Huntington Avenue, Boston, MA 02115, USA; <sup>2</sup>Harvard University, Cambridge, MA; <sup>3</sup>Unidad de Análisis Económico, Secretaría de Salud, México DF, Mexico; <sup>4</sup>Instituto Nacional de Psiquiatría Ramón de la Fuente Muñiz, México DF; <sup>5</sup>Boston Center for Refugee Health and Human Rights, Boston Medical Center, Boston, MA; <sup>6</sup>Harvard School of Public Health, Boston, MA; <sup>7</sup>University of California, Berkeley, CA; <sup>8</sup>Organisation for Economic Co-operation and Development, Paris, France; <sup>9</sup>University of California, San Francisco, CA; <sup>10</sup>Instituto Mexicano del Seguro Social, México DF

### Abstract

**Objective** To inform decision making regarding intervention strategies against non-communicable diseases in Mexico, in the context of health reform.

**Design** Cost effectiveness analysis based on epidemiological modelling.

**Interventions** 101 intervention strategies relating to nine major clusters of non-communicable disease: depression, heavy alcohol use, tobacco use, cataracts, breast cancer, cervical cancer, chronic obstructive pulmonary disease, cardiovascular disease, and diabetes.

**Data sources** Mexican data sources were used for most key input parameters, including administrative registries; disease burden and population estimates; household surveys; and drug price databases. These sources were supplemented as needed with estimates for Mexico from the WHO-CHOICE unit cost database or with estimates extrapolated from the published literature.

**Main outcome measures** Population health outcomes, measured in disability adjusted life years (DALYs); costs in 2005 international dollars (\$Int); and costs per DALY.

**Results** Across 101 intervention strategies examined in this study, average yearly costs at the population level would range from around

≤\$Int1 m (such as for cataract surgeries) to >\$Int1 bn for certain strategies for primary prevention in cardiovascular disease. Wide variation also appeared in total population health benefits, from <1000 DALYs averted a year (for some components of cancer treatments or aspirin for acute ischaemic stroke) to >300 000 averted DALYs (for aggressive combinations of interventions to deal with alcohol use or cardiovascular risks). Interventions in this study spanned a wide range of average cost effectiveness ratios, differing by more than three orders of magnitude between the lowest and highest ratios. Overall, community and public health interventions such as non-personal interventions for alcohol use, tobacco use, and cardiovascular risks tended to have lower cost effectiveness ratios than many clinical interventions (of varying complexity). Even within the community and public health interventions, however, there was a 200-fold difference between the most and least cost effective strategies examined. Likewise, several clinical interventions appeared among the strategies with the lowest average cost effectiveness ratios—for example, cataract surgeries.

**Conclusions** Wide variations in costs and effects exist within and across intervention categories. For every major disease area examined, at least some strategies provided excellent value for money, including both population based and personal interventions.

Correspondence to: J A Salomon jsalomon@hsph.harvard.edu

Extra material supplied by the author (see <http://www.bmj.com/content/344/bmj.e355?tab=related#webextra>)

General appendix (referred to by all the papers in this cluster)

Technical appendix: details of methods and assumptions used in modelling population health effects, costs, and cost effectiveness

Appendix table: Costs, population health effects, and cost effectiveness for 101 interventions in Mexico, by disease cluster

Appendix figure: Comparison of yearly population health effects for all interventions under scenarios with and without age weights

## Introduction

In 2003, Mexico introduced a major health reform that created the System of Social Protection in Health (SSPH).<sup>1</sup> SSPH generated new financial rules to fund population based interventions for all Mexicans regardless of their insurance status and personal healthcare interventions for those without access to social security (about half of the total population). The latter were financed through an insurance based component called Seguro Popular. Through the reforms, public expenditure for the uninsured increased substantially,<sup>2</sup> with the overall budget for the Ministry of Health rising by almost four times in real terms between 2001 and 2010.<sup>3</sup> By the end of 2010, the number of Seguro Popular beneficiaries had reached over 43 million, 88% of the previously uninsured target population.<sup>4</sup>

During the planning and design of the reform, rigorous evidence was needed on the magnitude of different health problems and on the benefits and costs of different health interventions. Decisions to include new interventions in explicitly defined packages of services were informed by a deliberative process that included an analytical priority setting exercise based on measurement of the burden of disease and cost effectiveness of different candidate interventions.<sup>5</sup> States in Mexico are required to provide all interventions included in three minimum packages of services comprising community and public health interventions; low and medium complexity clinical services; and high complexity clinical services, each financed through separate funding mechanisms. As part of the process of defining the content of these packages during 2004–6, we undertook cost effectiveness analyses for a wide array of health interventions spanning major causes of disease burden in Mexico. The overall process of defining the content of the service packages was intended to be evidence based, equitable, transparent, and contestable. After the reform, evidence on cost effectiveness continues to inform decision making regarding amendments to the packages of services covered by SSPH; state level policies regarding coverage of interventions additional to the defined minimum packages; and broader debates over the advantages and disadvantages of explicit packaging based in part on economic evidence—for example, among social security institutions in Mexico that do not currently base coverage decisions on explicit packages of interventions.

This paper—as part of a series on the cost effectiveness of interventions for non-communicable disease and injury in economically developing regions of the world—reports on cost effectiveness analyses for 101 intervention strategies directed at nine major clusters of non-communicable diseases in Mexico.

## Methods

Our analyses focused on interventions related to the following nine disease areas that are major contributors to the overall burden of disease in Mexico<sup>5 6</sup>: depression, heavy alcohol use, tobacco use, cataracts, breast cancer, cervical cancer, chronic obstructive pulmonary disease, cardiovascular disease, and diabetes. Interventions for analysis were selected in consultation with the Ministry of Health in Mexico, based on policy priorities and ongoing debates regarding the content of packages of services in SSPH. Intervention definitions were developed according to standards of quality care and available evidence on effectiveness. The table<sup>||</sup> summarises the main types of interventions analysed in this study, noting the specific package of services for which each type of intervention was considered. The technical appendix on bmj.com provides a full listing and definitions of the 101 specific interventions that we evaluated.

The overall analytical approach used in this study adhered to recommendations for undertaking generalised cost effectiveness analysis in the WHO-CHOICE framework.<sup>7</sup> Where prior regional analyses were available from the WHO-CHOICE project,<sup>8–13</sup> we used similar intervention definitions, modelling approaches, and costing methods. Here we summarise the methods and assumptions used in the analyses. Further details are provided in the technical appendix on bmj.com.

## Analytic overview

To compute the effectiveness of an intervention targeting a particular health problem in terms of net changes in population health, we first defined the current epidemiology of the health problem, building on a linked study to measure the burden of disease in Mexico.<sup>6</sup> Intervention effectiveness was expressed in terms of changes in disease model parameters—that is, as changes in rates of incidence, prevalence, case fatality, or remission or changes in health state valuations that reflect the severity of a particular health outcome. We used a population model to translate information on disease dynamics into generic, comparable measures of population health, expressed as disability adjusted life years (DALYs). In line with WHO global burden of disease estimation,<sup>14</sup> the Mexican national burden of disease assessment related to this project,<sup>6</sup> and standard WHO-CHOICE methods,<sup>7</sup> DALYs averted were discounted (at 3% a year) and age weighted (see also the general appendix on bmj.com). Costs were evaluated from a societal perspective, within three broad categories: patient costs, programme costs, and training costs. Costs were expressed as international dollars (\$Int) at 2005 prices, discounted at 3% a year according to CHOICE standards.<sup>7</sup> International dollars represent a hypothetical currency that allows for the same quantities of goods or services to be purchased regardless of country, standardised on purchasing power in the United States.

## Data sources

We used Mexican data sources when possible, drawing extensively on four main local sources: administrative registries, population estimates, household surveys, and drug cost databases.

### Administrative registry data

Information on age specific mortality and causes of death are compiled from death certificates by the Ministry of Health and the Instituto Nacional de Estadística y Geografía. Additionally, public institutions providing hospital services maintain discharge registries, which include patient level information on sociodemographic characteristics, causes of admission to hospital classified by ICD-10 codes (international classification of diseases, 10th revision), diagnostic and treatment procedures coded according to ICD-9-CM, result of procedures, mortality in hospital, reasons for discharge, number of hospital bed days, and insurance status. For the present analyses, we used mortality data from the year 2004. We used discharge registries from Ministry of Health hospitals for the years 2000–5 and from hospitals affiliated with the Instituto Mexicano del Seguro Social (IMSS) for the years 2004 and 2005.

### Population estimates

Population estimates for 2000–5 were provided by the Consejo Nacional de Población (CONAPO), which develops yearly projections of population numbers by age, sex, state, and insurance status. Projections are made based on official surveys

including the National Survey on Fertility and Health, censuses and special surveys relating to migration.

### *Population household surveys*

The Encuesta Nacional de Salud y Nutrición 2005–6 (ENSANut) was a nationally and state representative survey that sampled 47 695 households and 206 700 individuals. Modules in ENSANut included information on household characteristics, health insurance, risk factors (smoking and alcohol use), health states, and use of services. Biomarkers were collected on concentrations of cholesterol, plasma glucose, and haemoglobin A<sub>1c</sub> and blood pressure. ENSANut 2005–6 was used in this analysis primarily to measure current coverage of selected interventions.

### *Drug cost database*

Public institutions providing healthcare in Mexico are required to purchase only drugs included in the Cuadro Básico de Medicamentos (Mexican Positive List, MPL). Public purchasing regulations require public bidding for multiple source drugs, although there is no general consolidated purchase system for the whole public health sector, as all institutions are essentially independent. We used the 2005 purchase price database available from IMSS, which is the largest public purchaser in Mexico.

## **Estimation of intervention effects**

### *Epidemiological estimates*

For most interventions, current epidemiology of relevant diseases or injuries was defined based on results from the Mexican burden of disease analysis,<sup>6</sup> expressed in terms of age and sex specific incidence, prevalence, case fatality, remission, and mortality. Vital registration data for 2004 were used to estimate mortality by age, sex, and cause. Total mortality figures by age and sex were adjusted with standard demographic techniques to account for under-recording of deaths at certain ages, misreporting of age on the death certificate, and migration.<sup>15 16</sup> Estimates for causes of death were adjusted following standard algorithms for redistributing deaths coded to “ill defined” disease or injury categories, cancers of unknown sites, and cardiovascular disease, as well as miscoding of diabetes to cardiovascular or other chronic diseases.<sup>6 17–19</sup> Estimates of the incidence of different diseases and their relevant sequelae by age and sex were derived from a combination of sources and imputation approaches applied to different groups of causes.<sup>6</sup>

### *Intervention definitions*

The selection and specification of interventions, in cases where a WHO-CHOICE regional analysis was available, corresponded closely to the interventions defined in the prior analysis. In cases where no WHO-CHOICE regional analysis was available, the choice of interventions was guided by consultation with experts in Mexico or by existing norms for clinical practice in Mexico. Definition of interventions, in general, was as explicit as possible and specified both immediate components of intervention delivery as well as the types of actions that would be undertaken in response to downstream consequences of the disease process or of the intervention itself.

### *Intervention effectiveness*

The definition of the current epidemiology, combined with information on current coverage and effectiveness of interventions, served as the analytic starting point for defining

all intervention scenarios, including the null scenario. Following the standard WHO-CHOICE approach, we derived intervention effectiveness from meta-analyses and systematic reviews where these were available. For interventions that were examined previously in WHO-CHOICE regional analyses, we maintained consistent assumptions about intervention efficacy unless there was sufficient evidence to suggest different outcomes in Mexico. For incorporation into the population model described below, intervention effectiveness was translated into changes in relevant disease model parameters. For example, the effects of primary prevention were expressed as percent reductions in age and sex specific incidence rates from a particular condition, while treatment interventions were allowed to affect transitions to other disease states, remission rates, case fatality rates, or health state valuations. Details on the parameters of effectiveness for specific intervention analyses are provided in the technical appendix on bmj.com, including a full listing of data sources on effectiveness.

### *Population health outcomes*

Population health outcomes under different intervention scenarios were modelled with the multistate population model PopMod<sup>20</sup> (see general appendix on bmj.com) or analogous tools developed for this project where more detailed disease models were required. Interventions were compared with a null scenario, which was simulated by altering the baseline epidemiological parameters to remove the estimated effects of current intervention coverage. For intervention scenarios, effectiveness estimates were adjusted to account for target population coverage levels and provider and patient adherence to interventions. Each intervention scenario assumed implementation of the intervention for a 10 year period, but the population model captured all effects over a 100 year time horizon. For both the null and intervention scenarios, the inputs to the population model included rates of incidence, remission, and case fatality; estimates of prevalence; and health state valuations for relevant outcomes. Outputs from the model included estimates of the residence time in each disease state and total number of healthy life years lived by age, sex, and calendar year. These outputs were used to calculate intervention effectiveness in terms of changes in aggregate population level health outcomes. Where alternatives to PopMod were used for specific analyses, these alternative modelling approaches are described in the technical appendix on bmj.com.

## **Estimation of intervention costs**

We used an ingredients approach to costing, by which the quantities of inputs that are used in delivering a particular service or intervention are multiplied by their unit prices to obtain total costs. Following the standard WHO-CHOICE approach, we considered three broad categories of costs: patient costs, programme costs, and training costs.

### *Patient costs*

Patient level costs included hospital bed days, hospital visits, health centre visits, ancillary care, laboratory and diagnostic tests, drugs, and other costs related to specific interventions. Resource quantities were derived through review of the published literature, and from practice guidelines. Drug prices were taken from the IMSS purchase price database. Unit prices for non-traded goods, including patient services such as hospital bed days, were standardised across intervention analyses and derived from the WHO-CHOICE price database, which includes



country specific estimates based on an econometric analysis of multinational datasets on costs.<sup>21</sup>

### Programme costs

We considered several key categories of programme activities. Basic administration includes planning and overhead costs, in addition to staff required to effectively monitor, evaluate, and supervise the programme. These costs depend on whether the intervention requires legislation, the level at which administration is required, and the complexity of monitoring and evaluation needed. Other categories of programme costs relevant to certain interventions included media campaigns, other information, education or communication activities, and law enforcement. For most interventions, we adopted estimates of resource use and prices for programme cost components from previous WHO-CHOICE regional analyses. Details on assumptions of programme costs for specific analyses are in the technical appendix (see [bmj.com](http://bmj.com)).

### Training costs

Training costs, relevant for some interventions, depend on the length of training required, the number of supervisory visits needed a year, and the capacity for a single training session. All interventions in this study that required training costs were linked to previous WHO-CHOICE regional analyses, and we maintained the assumptions from these previous analyses.

### Estimation of cost effectiveness

We computed total costs for a given intervention as the sum of all patient, programme, and training costs. The null scenario by definition includes no costs, so costs of all other interventions can be interpreted as being incremental on the null. The total health benefits of an intervention were computed by comparing the number of healthy life years lived in the population in a particular intervention scenario with the total number of healthy life years lived in the population under the null scenario. In the base case, we used discounted age weighted DALYs as the unit of account for healthy life years, but we also conducted a sensitivity analysis comparing these results with those without age weighting.

For all interventions, we report annualised quantities for both total costs and total benefits. For total costs, these were derived simply by dividing the costs over the 10 year intervention period by 10. For total benefits, these were derived by taking the full difference in health effects over the 100 year modelled period and dividing this by 10. In this way, the annualised costs and benefits can be interpreted as the costs and benefits associated with a single year of intervention. We report average cost effectiveness ratios for interventions, ordered by increasing overall effects. Average cost effectiveness ratios are interpretable as the net costs per unit of net benefit associated with delivering the intervention, compared with doing nothing. We also report incremental cost effectiveness ratios where these measures are relevant—that is, in evaluating mutually exclusive interventions that represent competing choices. Incremental cost effectiveness ratios were computed for an intervention with respect to the next most effective alternative after eliminating strategies that were dominated (that is, those that were more costly and less effective than other options) or those that were weakly dominated (that is, had higher cost effectiveness ratios than more effective options).

Following the standard benchmarks for value for money proposed in international work on cost effectiveness, we compared cost effectiveness ratios against thresholds defined

in reference to the gross domestic product (GDP) per capita in Mexico, which was \$Int10 770 in 2005. Interventions were considered to be highly cost effective when they had ratios that fell below the per capita GDP and were regarded as being potentially cost effective if they had ratios between one and three times per capita GDP.

## Results

### Overview

The figure<sup>1</sup> summarises information on costs, population health effects, and cost effectiveness (compared with the null) for all interventions. Across the 101 interventions examined in this study, the average yearly costs at the population level ranged from  $\leq$ \$Int1m (for cataract surgeries and some elements of cervical cancer treatment) to  $>$ \$Int1bn (for high coverage of treatment for hypercholesterolaemia or aggressive management of absolute cardiovascular risks). Comparing the total annualised population health benefits across interventions, we again observed a wide range of outcomes, from  $<1000$  DALYs averted a year (for some components of cancer treatments or aspirin for acute ischaemic stroke) to  $>300\,000$  DALYs averted a year (for aggressive combination of interventions to deal with alcohol use, which was the leading risk factor for the burden of disease in Mexico in 2004,<sup>6</sup> and cardiovascular risks).

In the figure<sup>1</sup>, with both axes displayed on a log scale, diagonal lines moving from the lower left to the upper right direction are cost effectiveness isoquants, which means that any point on the same line as another point has the same average cost effectiveness ratio compared with the null. Thus, these figures offer an easy graphical display of broad bands of cost effectiveness across interventions. The interventions in this study spanned a wide range of average cost effectiveness ratios, differing by more than three orders of magnitude between the lowest and highest ratios. At the low end, some interventions cost  $<$ \$Int100 per DALY averted, such as taxation interventions for alcohol. At the high end, we identified interventions that cost  $>$ \$Int100 000 per DALY, such as high intensity treatment for chronic obstructive pulmonary disease or aspirin for acute ischaemic stroke.

### Comparison across intervention packages

The interventions in this analysis pertained to three different packages of interventions covered by the health reform scheme: community and public health interventions; low and medium complexity clinical interventions; and high complexity clinical interventions. The reform specified that each of these categories of interventions should be financed from a separate fund. The figure<sup>1</sup> distinguishes interventions falling into these three broad categories. The community and public health interventions included non-personal interventions for alcohol use, tobacco use, and cardiovascular risks; and screening for breast cancer and cervical cancer. Overall, the community and public health interventions tended to have high benefits and medium level overall costs and tended to have lower cost effectiveness ratios than many of the interventions in the other two categories. Even within the community and public health interventions, however, there was more than a 200-fold difference between the highest and lowest cost effectiveness ratios.

Low and medium complexity healthcare interventions included personal services for alcohol use, tobacco use, and cardiovascular disease prevention; treatment for chronic obstructive pulmonary disease; interventions for depression; cataract surgery; and secondary prevention for diabetes. High complexity healthcare interventions included treatment for

ischaemic heart disease, stroke, and congestive heart failure and treatment for breast cancer and cervical cancer. In terms of total costs and total benefits, the high complexity interventions tended to have lower totals than the low and medium complexity interventions, mainly because the target populations for these services were smaller on average. In terms of cost effectiveness ratios, on the other hand, there was little discernable difference between the two groups of interventions. Cost effectiveness ratios both for low and medium complexity interventions and for high complexity interventions spanned ranges of more than three orders of magnitude.

## Results by disease cluster

Full results on the yearly costs, population effects, and cost effectiveness ratios for all 101 interventions are provided in the appendix table on [bmj.com](http://bmj.com). Here we summarise the costs, effects, and average cost effectiveness results by intervention cluster. The average cost effectiveness ratio can be understood as the cost effectiveness of an intervention compared with a null scenario (no intervention). When we compare mutually exclusive interventions within a cluster, we also describe incremental cost effectiveness ratios, which were based on the net costs and net effects of an intervention compared with the next most effective, non-dominated intervention.

**Depression**—We evaluated four main interventions for the treatment of depression—older antidepressant drugs (tricyclic antidepressants), newer antidepressants (selective serotonin reuptake inhibitors), psychotherapy, and proactive case management—as well as various combinations of these interventions. We found that proactive care combined with older or newer antidepressants had the biggest impact on population health, averting almost double the number of DALYs averted by psychotherapy or antidepressants alone. All examined strategies had average cost effectiveness ratios below the per capita GDP in Mexico for each DALY averted, making them cost effective by international standards. Regarding all interventions and combinations as mutually exclusive competing choices, we found that two interventions dominated all others: newer antidepressants compared with the status quo, which had an incremental cost effectiveness ratio <\$Int1500 per DALY averted, and the combination of newer antidepressants with psychotherapy and proactive management, which had an incremental cost effectiveness ratio around \$Int3400 per DALY averted.

**Heavy alcohol use**—We evaluated five main types of interventions for heavy alcohol use (including taxation at various levels, random roadside breath testing, brief advice in primary healthcare, reduced access at retail sales locations, and a comprehensive advertising ban) as well as various combinations of these interventions. We found that taxation interventions produced the highest overall population health benefits and were also among the lowest cost interventions in this group. The taxation interventions, along with interventions to reduce retail access and limit advertising, all had highly attractive cost effectiveness ratios compared with doing nothing (<\$Int350 per DALY averted, or <\$Int100 per DALY averted in the case of the tax interventions). Even the interventions with the highest cost effectiveness ratios in this cluster (breath testing and brief physician advice) had costs per DALY below the per capita GDP of Mexico, making them highly cost effective by international standards. Considering the incremental costs and effects of interventions treated as competing choices, we found that an aggressive tax increase had an incremental cost effectiveness ratio of only \$Int72 per DALY averted compared with the null (and dominated the status quo); adding a ban on

advertising yielded an incremental cost effectiveness ratio of \$Int320 per DALY averted compared with only the tax increase. Combining the tax increase, advertising ban, brief advice, and reduced access had an incremental cost effectiveness ratio around \$Int1800, and adding roadside breath testing produced an incremental cost effectiveness ratio around \$Int10 900, which is close to the GDP per capita in Mexico.

**Tobacco use**—We evaluated four main types of interventions for tobacco use (taxation at different levels, clean indoor air law enforcement, nicotine replacement therapy, and a comprehensive advertising ban) and several combinations of these interventions. As with alcohol, we found that taxation interventions were effective in terms of population health benefits, inexpensive compared with other interventions, and highly cost effective. A comprehensive advertising ban and clean air law enforcement would also be characterised as highly cost effective using the benchmark of averting each DALY at a cost of less than Mexico's GDP per capita, whereas nicotine replacement therapy exceeded the threshold of three times GDP per capita per DALY averted, which made this intervention not cost effective according to international standards. In the incremental analysis, increased taxation had an incremental cost effectiveness ratio of around \$Int140 per DALY averted compared with the status quo; adding a ban on advertising produced an incremental cost effectiveness ratio of \$Int2800.

**Cataract**—The only effective treatment for cataracts is cataract surgery to remove the opacified lens. We evaluated two different types of cataract surgery: conventional extracapsular cataract extraction and phacoemulsification. Both procedures were assessed at three target coverage levels (50%, 80%, and 95%) for a total of six separate intervention analyses. Both surgeries, at any coverage level, were found to have average cost effectiveness ratios below \$Int100, making them among the most cost effective of all interventions examined across different clusters. In terms of comparisons between the different types, phacoemulsification dominated extracapsular cataract extraction at any given coverage level. At a coverage of 95%, phacoemulsification had an incremental cost effectiveness ratio of \$Int43 per DALY averted compared with extracapsular cataract extraction at 95% coverage.

**Breast cancer**—We evaluated treatment of breast cancer, including a disaggregated analysis of costs and effects of treatment at different stages, as well as a strategy of treatment plus routine population screening according to the Mexican norm at the time of analysis. Considering the benefits of treatment, we found that treating tumours at earlier stages contributed greater health benefits overall than treatment at later stages and that population screening, while costly, would provide substantial additional benefits over clinical detection. The cost effectiveness ratios for breast cancer treatment fell below Mexico's per capita GDP per DALY averted, making treatment highly cost effective. Adding screening to treatment according to the norm at the time of analysis had an incremental cost effectiveness ratio of \$Int22 000 (that is, falling between one and three times GDP per capita for each DALY averted), implying that screening would be potentially cost effective, but not highly cost effective according to international benchmarks.

**Cervical cancer**—Analyses for cervical cancer, similarly to the breast cancer analyses, evaluated strategies for treatment without screening or treatment combined with routine population screening according to the Mexican norm. The overall findings for cervical cancer interventions mirrored those for breast cancer, with treatment at earlier stages (including the precancerous stage of cervical intraepithelial neoplasia, grade II or III) contributing greater benefits than treatment at later stages. Even the relatively

more costly and less effective treatments of later stages of cancer were found to be cost effective components of the overall treatment strategy, based on falling below the threshold of per capita GDP for each DALY averted. For cervical cancer, screening was among the most efficient strategies, increasing overall benefits more than 10-fold. The incremental cost effectiveness ratio for screening and treatment, compared with treatment without screening, was around \$Int5600 per DALY averted, which implied that screening would be highly cost effective.

**Chronic obstructive pulmonary disease**—Current interventions for chronic obstructive pulmonary disease (COPD) are aimed at slowing the progression of the decline in lung function associated with the disease. We evaluated five main interventions: intensive smoking cessation programme for current smokers with a diagnosis of COPD; influenza vaccination of COPD patients aged  $\geq 65$ ; inhaled bronchodilator for those with mild COPD; inhaled bronchodilator and corticosteroid for those with moderate to severe COPD; long term oxygen treatment (in addition to bronchodilator and corticosteroid) for those with severe COPD; and treatment of severe COPD exacerbations. We found that treatment of severe exacerbations associated with COPD averted the smallest number of DALYs, followed by long term oxygen treatment, inhaled bronchodilator for mild COPD, and then an inhaled bronchodilator plus inhaled corticosteroid for moderate to severe COPD. Influenza vaccine for people with COPD and an intensive smoking cessation programme for those diagnosed with COPD had the largest benefits in terms of DALYs averted and were less expensive than interventions directed solely at patients with later stages of disease. These were also the only two interventions with average cost effectiveness ratios below three times GDP per capita in Mexico (both having ratios between \$Int2500 and \$Int5000). Given the focus of the different interventions on different target populations, we did not conduct an incremental analysis treating the interventions as competing choices.

**Cardiovascular disease**—We evaluated a wide range of interventions for primary prevention, treatment, and secondary prevention for cardiovascular disease. Prevention interventions included non-personal interventions involving health education through mass media programmes, legislation or voluntary agreements with the food industry, as well as personal health service interventions including detection and treatment of high risk individuals based on blood pressure, serum cholesterol, and absolute risk thresholds. The absolute risk approach estimates the combined risk of a cardiovascular event over the next decade above a given threshold, based on relative risk estimates of modelled risk factors. We also assessed 30 single interventions and combinations of interventions for treatment and secondary prevention relating to acute myocardial infarction, stroke, and congestive heart failure. All primary prevention interventions were found to be highly cost effective according to international benchmarks. Among population level (non-personal) interventions, those aimed at reducing blood pressure and cholesterol, and salt reduction through legislation, had the lowest costs per DALY. Individual primary prevention interventions resulted in much greater effectiveness, although they were more costly per unit of health benefit than the population-wide strategies. In incremental analyses, population salt reduction, a comprehensive population combination intervention, and absolute risk threshold approaches dominated all individual strategies focusing on either hypertension or cholesterol alone. The most aggressive strategy based on absolute risk thresholds, focusing on all patients with risks above 5%, was the most

effective but at an incremental cost effectiveness ratio that was well above the benchmark of three times GDP per capita. All treatment interventions for myocardial infarction were found to be highly cost effective or cost effective in comparing average cost effectiveness ratios to GDP based benchmarks, with cardiac rehabilitation producing the most attractive cost effectiveness ratios because of the relatively low cost of this intervention combined with moderate population level health effects. For stroke, only post-acute stroke interventions were found to be highly cost effective, while interventions targeting the acute period resulted in low health gains at significantly higher costs. All heart failure interventions were highly cost effective, with diuretics being the most cost effective in the group. Because the set of interventions were not mutually exclusive, we have not reported on a full set of incremental comparisons for the cluster of interventions relating to cardiovascular disease.

**Diabetes**—We evaluated four main interventions for secondary prevention of type 2 diabetes: blood pressure control, lipid control, and conventional or intensive glycaemic control. With a high overall prevalence of diabetes in Mexico, the largest population benefits would be realised through glycaemic control. The average cost effectiveness ratios for conventional and intensive glycaemic control were about \$Int12 500 and \$Int13 600 per DALY averted, respectively, implying that glycaemic control is potentially cost effective at less than two times per capita GDP. Considering the incremental cost effectiveness of intensive compared with conventional glycaemic control, the more intensive strategy had an incremental ratio of around \$Int16 900. Lipid control for patients with diabetes would produce a much smaller overall population benefit, but at an average cost effectiveness ratio similar to that for glycaemic control. Blood pressure control would produce an overall benefit between that for lipid control and that for glycaemic control. The cost effectiveness ratio for blood pressure control, however, was considerably lower than those for the other two interventions. At around \$Int8500 per DALY averted, blood pressure control would be classified as highly cost effective according to standard international benchmarks.

## Sensitivity of results to choice of health metric

In our base case analysis, we have focused on measuring population health effects of interventions using DALYs that reflect differential age weights, such that health outcomes experienced during young adulthood are weighted more heavily than those during childhood or older adult years. We examined the sensitivity of results to the inclusion of age weights by recalculating all health effects and cost effectiveness ratios with equal weights at all ages. The appendix figure on bmj.com compares the yearly population health effects for all 101 intervention strategies under scenarios with and without age weights, indicating a high degree of consistency. Examining the average cost effectiveness ratios in the scenario without age weighting (shown for all interventions in the appendix table on bmj.com), we found that only two interventions moved from one broad category (that is, highly cost effective, potentially cost effective, not cost effective) to another. These were nicotine replacement therapy, which shifted from not cost effective to potentially cost effective with the removal of age weights, and angiotensin converting enzyme (ACE) inhibitors for acute myocardial infarction, which shifted from potentially cost effective to highly cost effective; both of these shifts were based on relatively small changes in the ratios. Overall, this analysis indicated that the results in general were highly robust to the



choice of age weighted DALYs averted as the primary indicator of population health benefits.

## Discussion

In this study we estimated the population health impacts and costs for various interventions targeting non-communicable diseases in Mexico. As in the companion papers in this series presenting analyses for two world regions,<sup>22-28</sup> we found wide variation across interventions in both costs and effects; yet we also observed that, in every major disease cluster we examined, at least some of the interventions provided excellent value for money. At the high value end of the spectrum, several interventions cost <\$Int250 for each year of life they added to the population—including interventions aimed at heavy alcohol use, tobacco use, cataracts, and cardiovascular disease risks. At a small fraction of the per capita income in Mexico, such gains are considered to be exceptionally good value, based on standard benchmarks for cost effectiveness analysis.

Economic evaluations in middle income countries like Mexico often require extrapolation of evidence and assumptions from other countries or from regional databases.<sup>29</sup> In our analysis, the availability of local epidemiological and economic information, and explicit consideration of local norms for clinical and public health practice, helped to reveal limitations in the transferability of conclusions from one setting to another and to develop national estimates of cost effectiveness for selected interventions. For example, distinct features of the screening norm in force for breast cancer in Mexico have important implications for analysis of the economic efficiency of different intervention strategies. We found that the aggressive screening policy in place in Mexico for early detection of breast cancer had an estimated cost effectiveness ratio between one and three times GDP per capita, despite guidelines in other countries such as the US that discourage testing before age 50.<sup>30</sup> As further liberalisation of Mexican norms for early breast cancer screening since July 2011 begins to shape practice, information on costs and expected health effects of wider screening coverage is essential in preparing for the expected increase in demand for screening services. Another example of the importance of incorporating local information in economic evaluation relates to variation in costs of interventions. For interventions with intensive use of drugs, differences across settings in purchasing practices can have an important effect on the costs of these interventions.

Analyses of the cost effectiveness of an array of interventions across categories ranging from community services to high intensity clinical services offers insights that in some cases contradict the conventional wisdom on value for money within broad categories of interventions. It is not the case that all community and public health interventions have extremely low cost effectiveness ratios; neither is it true that high complexity interventions are universally expensive in relation to the health gains they provide. Cataract surgery seems to be among the best buys in health interventions in Mexico, less expensive per unit of health benefit than increasing taxation of tobacco products, itself a highly cost effective intervention at a little more than \$Int100 per healthy year gained. Likewise, other clinical services such as antidepressants and some interventions for secondary prevention of cardiovascular disease have cost effectiveness ratios that are well below the threshold of GDP per capita for each DALY averted. Thus, where conventional wisdom on value for money in public health and medicine fails to provide an adequate basis for intervention choice, the development of rigorous information on costs and health benefits from a wide

range of intervention strategies offers essential information to planners and policy makers in resource constrained settings.

Information on the cost effectiveness of interventions provides a formal basis for evaluating efficiency of allocated resources, to maximise overall population health gains under resource constraints. As such, cost effectiveness is only one consideration among a range of important criteria in setting priorities for health interventions or designing and evaluating healthcare reform. In addition to attaining high overall gains in population health, decision makers in Mexico, as elsewhere, are also concerned with ensuring that benefits are distributed equitably across the population. Much has been written about concerns for fairness with respect to the Mexican reform, and these concerns were central to the design of the reform and to its subsequent critical evaluation.<sup>31-33</sup>

Another limitation is that the analyses presented here, while covering a broad scope of different interventions, inevitably omit some interventions that are relevant to clinical practice and health policy. For example, although we report on secondary prevention for managing risk factors in diabetes, we have not evaluated the range of available strategies relating to screening and treatment for microvascular complications of diabetes. On the other hand, we included in our analyses a strategy of intensive glycaemic control for diabetes, even as recently revised guidelines have prompted debate over the pros and cons of such a strategy.<sup>34 35</sup> As another example, we report here on two types of surgery for cataracts used widely in

Mexico—phacoemulsification and conventional extracapsular cataract extraction—but we have not yet evaluated manual small incision cataract surgery. As clinical practice guidelines constitute a moving target, and as new information emerges on health outcomes and resource requirements associated with interventions against chronic diseases and other health challenges, cost effectiveness analyses require periodic updating and revision to incorporate the best currently available evidence and to answer the most urgent policy questions.

We also recognise that this study—in presenting an expansive overview on the range of analyses undertaken across disease clusters—has summarised results relatively parsimoniously, without exhaustive details on uncertainty around each point estimate or sensitivity of each result to particular parameter values and assumptions. Specific choices with regard to technology adoption or detailed practice guidelines demand more precision than what is offered here, along with a more comprehensive characterisation of key uncertainties. The intent in this study, on the other hand, was to offer a broad perspective on the comparative costs and health impacts of a wide array of different interventions and strategies, in view of high level decision making in the context of health reform. To date, the results from this study have provided a methodological foundation for further work on cost effectiveness analysis by interdisciplinary teams within the Mexican Ministry of Health, at the same time that the findings have informed decision making around provision and financial coverage for several interventions and provided an evidence base for other public health policies. Specific examples include design of national programmes such as the breast cancer and cervical cancer screening, diagnosis, and treatment programmes, and national legislation such as the General Law on Tobacco Control. These results have also been referenced in discussions around accelerating or delaying coverage of specific interventions in SSPH.

Over the past 50 years, the epidemiological transition in Mexico has produced a dramatic rise in the importance of non-communicable diseases. Between 1955 and 2005, the proportion of all deaths from non-communicable diseases



increased from 23% to 75%.<sup>5</sup> This rise has presented new challenges to a health system that traditionally prioritised programmes for communicable disease and reproductive health. As major reforms in Mexico have sought to extend healthcare coverage to the substantial fraction of the population lacking insurance, and to develop new financial mechanisms to protect families from catastrophic health spending, evidence on the costs and health benefits associated with different types of interventions has been—and will continue to be—an essential input to the development of effective, efficient, and fair policies.

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**What is already known on this topic**

The advanced epidemiological transition in Mexico has produced a large and growing burden of non-communicable diseases

Health reforms since 2003 in Mexico have dramatically expanded insurance coverage in the population, prompting difficult policy choices on which services to provide to beneficiaries of the new social insurance programmes

**What this study adds**

An analysis of the cost effectiveness of 101 interventions targeting nine clusters of non-communicable diseases in Mexico showed that within each cluster there was at least one intervention that was considered to provide excellent value for money based on conventional benchmarks

High value can be found even among highly complex clinical services; conversely, public health strategies are not guaranteed to be highly cost effective

**Table****Table 1 | Summary of intervention strategies to reduce burden of non-communicable diseases in Mexico, by major disease cluster**

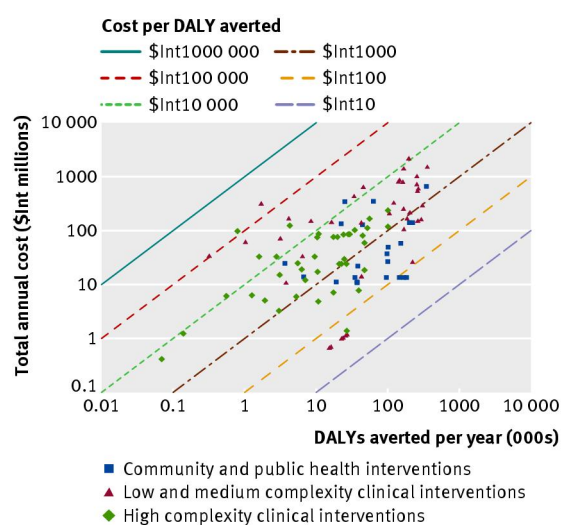
Disease cluster	Main intervention strategies analysed
Depression*	Tricyclic antidepressants, selective serotonin reuptake inhibitors, psychotherapy, proactive case management
Heavy alcohol use†	Excise taxes, advertising bans, random roadside breath testing, brief primary care advice*, restricted retail access
Tobacco use†	Excise taxes, advertising bans, indoor air laws, nicotine replacement therapy*
Cataracts*	Extracapsular cataract extraction, phacoemulsification
Breast cancer‡	Treatment (lumpectomy, radiotherapy, chemotherapy, mastectomy), screening (clinical examination and mammography)†
Cervical cancer‡	Treatment (lesion removal, radiotherapy, chemotherapy, surgery), screening (cervical smear test, liquid based cytology, HPV DNA testing)†
Chronic obstructive pulmonary disease*	Smoking cessation, influenza vaccination, inhaled bronchodilator, corticosteroid, treatment of severe exacerbations
Cardiovascular disease†	Health education through mass media, regulation of dietary salt, blood pressure, and cholesterol lowering drugs*, combined drug treatment for high risk patients*, single or combined drug regimens for acute and post-acute heart disease and stroke‡
Diabetes*	Treatment of hypertension, lipid control, glycaemic control

\*Low and medium complexity clinical interventions.

†Community and public health interventions (except where noted otherwise).

‡High complexity clinical interventions (except where noted otherwise).

## Figure



Costs, population health effects, and cost effectiveness of 101 intervention strategies in Mexico, by intervention package